

Optical Properties of Polymer Dispersed Cholesteric Liquid Crystals*

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Abstract. Polymer dispersed liquid crystals are composed materials consisting of micron-sized liquid crystal droplets dispersed in dielectric matrix. They have important applications as light shutters, flexible displays, switchable windows, temperature indicators, etc. In this work refractometric investigation of cholesteric liquid crystals, dispersed by ultrasonication in a polymer matrix, are reported. Refractive index measurements are performed at different wavelengths in the visible range and the liquid crystals RI dispersion behavior is determined.

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1 Introduction

Polymer dispersed liquid crystals (PDLC) [1-3] consist of micron-sized liquid crystal droplets dispersed in an optically transparent polymer matrix. These liquid crystal systems can be used as light shutters, flexible displays and switchable windows. Compact and reliable temperature indicators could be developed applying thermochromic cholesteric liquid crystals, which reflect definite colors at specific temperatures, in PDLC scattering devices – Figure 1.

In all cases of PDLCs' applications it's essential to know the disperse material's Refractive Index (RI) in order to predict its optical properties and to describe propagation of light in the medium. The RI determination using conventional methods is rather difficult because of PLCD film's turbidity. It can be noted that RI measurements with conventional Abbe and Pulfrich refractometers are not possible for samples with thickness less than 30 μm . The Method of the Disappearing Diffraction Pattern (MDDP) [4], which belongs to the methods

*This work is dedicated to Professor Alexander Derzhanski, DSci., Corresponding Member of the Bulgarian Academy of Sciences, on the occasion of his 70th anniversary.

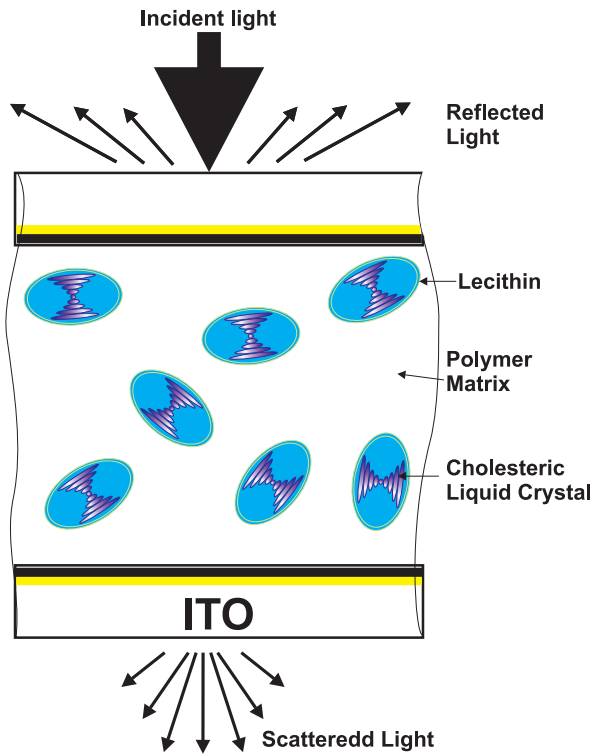


Figure 1. Cross-sectional view of a generalized PDLC thin film device

of the critical angle, allows measurements of the local RI near the surface of the investigated sample with a high accuracy and maximum simplicity. Another advantage of the MDDP is the possibility of measuring samples with thickness, comparable to the light wavelength, even in the case of slightly scattering or absorbing materials [5]. The dispersion behavior of the sample's RI in a wide spectral range can be studied using several discrete laser lines or monochromator [6,7].

2 Experimental results

2.1 Samples preparation

Polymethylmethacrylate (PMMA), L- α -phosphatidylcholine Soy bean lecithin (Sigma) and LC thermoindicator "Reachim" — Russia (Cr-40°C–Ch– 75°C– I) have been dissolved in chloroform in weight fractions ratio 0.34:0.04:0.62 and mixed by an ultrasonic mixer. A PDLCs in a liquid phase as well as deposited

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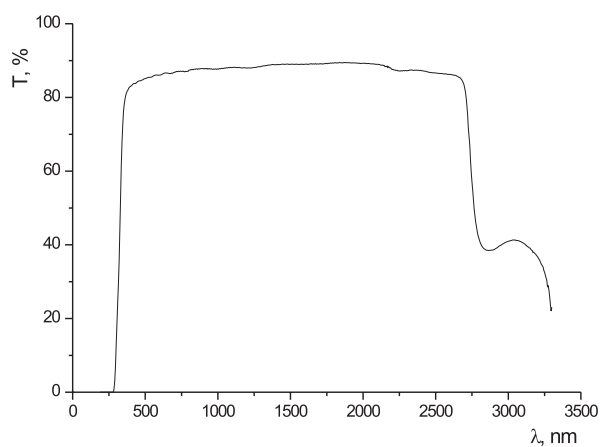


Figure 2. Transmission specter of the sample with thickness $5 \mu\text{m}$

as solid layers are investigated. The homogeneous liquid phase is obtained after mechanical stirring and sonication by UM-4 “Unitra”. Two types of solid layers on glass substrates have been prepared for RI measurements. First is spin-coated, the second is made by casting. Their average thickness is $5 \pm 1 \mu\text{m}$ and $20 \pm 1 \mu\text{m}$, respectively. The thinner sample has good transparency in 360–2600 nm spectral region, measured with Carry 5A spectrometer and illustrated in Figure 2.

The turbidity of the $20 \mu\text{m}$ sample is not an impediment to RI measurements by MDDP. The pictures of samples, made by microscope in transmission with 100x are shown in Figure 3.

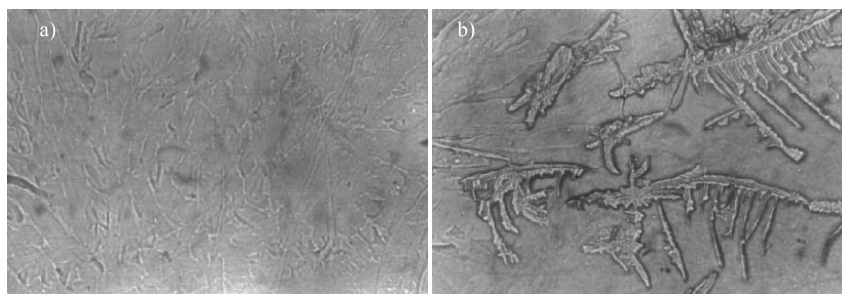


Figure 3. Microscopic pictures of the samples with thickness: a) — $5 \mu\text{m}$ and b) — $20 \mu\text{m}$

3 Refractive index measurements

The experimental setup for measuring of the samples' RI is shown in Figure 4. A layer of the liquid phase (4) is situated between a glass prism (3) and a metal diffraction grating (5). In the case of RI measurements of a solid layer the substrate and the layer are fixed between the prism and the grating by a index matching liquid. For small angles of incidence toward the prism/liquid interface, part

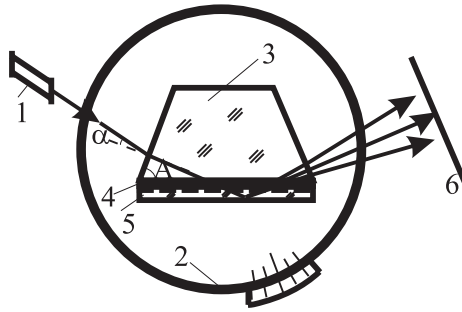


Figure 4. Experimental setup: 1 — laser, 2 — rotatory table with angular scale, 3 — glass prism, 4 — investigated layer, 5 — diffraction grating, 6 — screen

of the light refracts into the liquid, reaches the grating and diffraction pattern can be observed in reflection. If the angle of incidence is equal or beyond the angle of total internal reflection, the light totally reflects from the liquid and all diffraction orders have disappeared on the screen (6). The angle of incidence is changed and measured by the rotatory table (2) with angular scale and resolution of 1 arc. min. The sample's RI is calculated according [4]

$$n = N \sin \left(A \pm \arcsin \frac{\sin \alpha_{cr}}{N} \right) \quad (1)$$

where N and A are the prism's RI and refracting angle, respectively. The signs “+” and “-” correspond to clockwise and anti-clockwise laser beam rotation according to the normal position to the front prism's wall. The measurement's error depends mainly of uncertainty in the determined critical angle [4]

$$\Delta n = N \cos \left(A + \arcsin \frac{\sin \alpha_{cr}}{N} \right) (N^2 - \sin^2 \alpha_{cr})^{-1/2} \cos \alpha_{cr} \Delta \alpha_{cr} \quad (2)$$

The samples RI is measured with He-Ne laser ($\lambda = 633$ nm) and Ar laser ($\lambda = 488, 514.5, 646,$ and 676 nm). A prism, made of glass TF4 with high RI and refracting angle $A = 65^\circ$ is used in the experiments. The results from the measurements are presented in Figure 5.

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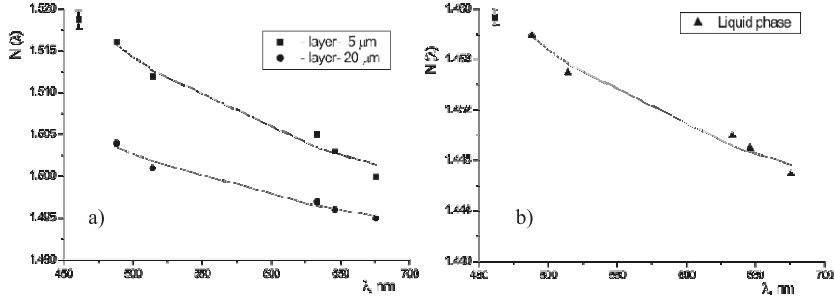


Figure 5. Refractive index of: **a)** layers with thickness 5 and 20 μm and **b)** liquid phase. The curves are the fitted dispersion dependences

The experimental points are fitted with a function

$$n^2 - 1 = \frac{s}{1 - \left(\frac{\lambda_s}{\lambda}\right)^2} \quad (3)$$

which corresponding to the Sellmeier dispersion equation, which are also shown as solid curves in Figure 5. The values of the calculated coefficients s and λ_s and the average quadratic deviation σ_n are presented in Table 1. The coefficients allow one to determine RI for any wavelength in the definition range 488–676 nm. The critical angle is measured with uncertainty of $5'$ in the case of the liquid phase and $10'$ — for measurements of the solid layers. This lead to an error in the calculated RI values of 1×10^{-3} and 2×10^{-3} , respectively, as is indicated in the Figure 5 as error bars.

Table 1. Coefficients in the Sellmeier dispersion equation

Media	s	λ_s , nm	σ_n
layer — 5 μm	1.2100	126.733	1.5×10^{-6}
layer — 20 μm	1.2098	97.845	3.8×10^{-7}
liquid phase	1.0662	111.427	7.8×10^{-7}

4 Conclusion

This work presents a refractometric investigation of cholesteric liquid crystals, dispersed in a polymer matrix. Two types of PDLCs are investigated — a liquid phase dissolved in chloroform and solid layers of the same PDLC deposited on glass substrates. Refractive index measurements are led in a spectral range from

488 to 767 nm and the samples RI's dispersion coefficients are determined. The MDDP is used in the experiments. The method allows calculation of the local RI near the surface's surface with a high accuracy and maximum simplicity. Moreover it's applicable for investigation of absorbing and scattering media. The measurements are not disturbed by surface gradients in the optical constants and sample's roughness. The last requirements are obviously essential for correct investigation of inhomogeneous samples as the solid layers of PDLCs.

References

- [1] P.S. Drzaic (1988) *Liq. Crystals* **3** 1543.
- [2] Dierking (2000) *Adv. Materials* **12** 167; D. Higgins (2000) *Adv. Materials* **12** 251.
- [3] G. Diankov, H. Naradikian, R. Tomova, T. Angelov (2003) in: *Nanoscience & Nanotechnology* **3**, eds. E. Balabanova, I. Dragieva; Heron Press, Sofia, pp. 241-242.
- [4] S. Sainov (1991) *Rev. Sci. Instrum.* **62** 3106.
- [5] Y. Sarov, M. Nikolaeva, M. Sendova-Vassileva, D. Malinowska, J. Pivin, (2003) *Vacuum* **69** 321.
- [6] V. Marinova, D. Petrova, M. Gospodinov, S. Dobрева (1997) *Mater. Res. Bull.* **32** 663.
- [7] V. Marinova, D. Petrova, M. Veleva (1998) *Cryst. Res. Technol.* **33** 119.